GERDA, a GERmanium Detector Array for the search for neutrinoless $\beta\beta$ decay in ^{76}Ge

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Abstract. The GERDA project, searching for neutrinoless double beta-decay of ^{76}Ge with enriched germanium detectors submerged in a cryogenic bath, has been approved for installation at the Gran Sasso National Laboratory (LNGS), Italy. The GERDA technique is aiming at a dramatic reduction of the background due to radioactive contaminations of the materials surrounding the detectors. This will lead to a sensitivity of about 10^{26} years on the half-life of neutrinoless double beta decay. Already in the first phase of the experiment, GERDA will be able to investigate with high statistical significance the claimed evidence for neutrinoless double beta decay of ^{76}Ge based on the data of the Heidelberg-Moscow experiment.

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Recent results coming from particle and astroparticle physics point towards a non-zero neutrino mass. In this exciting scenario, the observation of neutrinoless double beta decay would be of the utmost importance since it would at the same time establish the absolute neutrino mass scale, lepton number violation and the Majorana nature of neutrinos.
Experiments using germanium as source and detector for ^{76}Ge $0\nu\beta\beta$ decay have produced the best results up to now with lower limits on the half-life of $T_{1/2} > 1.9 \cdot 10^{25}$ y (90% CL) from the Heidelberg-Moscow experiment (exposure 35.5 kg·y) [1] and of $T_{1/2} > 1.57 \cdot 10^{25}$ y (90% CL) from the IGEX experiment (exposure 8.8 kg·y) [2]. From the data of the Heidelberg-Moscow experiment, the authors of [3] and [4] derive an evidence for the observation of neutrinoless double beta decay at 4.2σ based on 28.7±6.9 counts (over a background of about 60 events) in 71.7 kg·y, corresponding to a half-life of $1.19^{+0.37}_{-0.23} \cdot 10^{25}$ y. The GERDA (GERmanium Detector Array) experiment [5] is designed to clarify the situation and extend the range of accessible lifetimes.

DESCRIPTION OF THE EXPERIMENT AND PHYSICS REACHES

The experimental goal is to achieve a background index better than 10^{-3} counts/keV/kg/y in the $Q_{\beta\beta}$ region of ^{76}Ge (2039 keV). This is two orders of magnitude below what has been achieved by experiments so far. Such a background level would allow to run quasi background-free in the region of interest up to exposures of about 100 kg·y. The tremendous background reduction pursued by the GERDA experiment can be achieved using the concept first proposed in Ref. [6]. External γ radiation was found to be the main source of background in the Heidelberg-Moscow experiment. This can be effectively shielded by operating naked HP-Ge detectors suspended in a very high-purity cryogenic

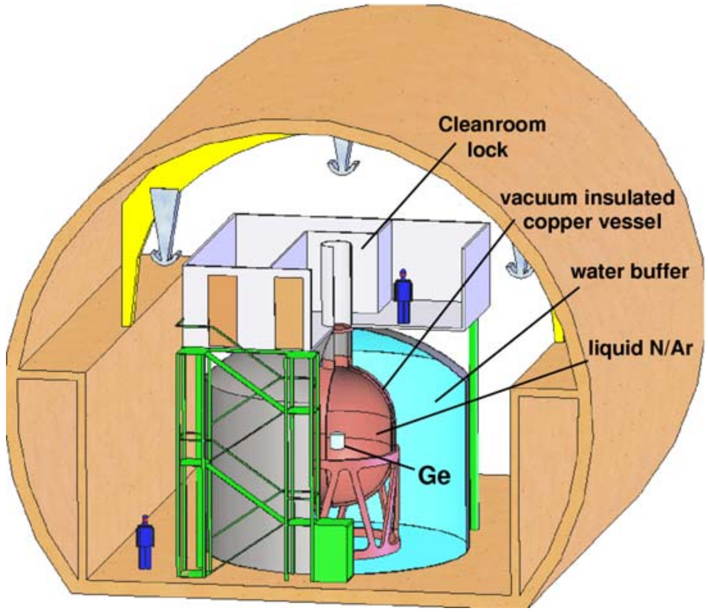

FIGURE 1. Conceptual design of the GERDA set-up

liquid.

The GERDA facility will be installed underground in the Hall A of the Gran Sasso National Laboratory, Italy. A schematic layout of the experiment is shown in Fig. 1. A compact array of enriched high-purity germanium detectors is suspended in the middle of a vacuum-insulated copper cryostat. The cryostat is filled with liquid nitrogen or argon. The cryoliquid acts at the same time as cooling medium and as a shield against the radioactivity from the environment and from the cryostat itself. Actually, also thanks to the R&D of the Borexino experiment, liquid nitrogen is probably one of the most radiopure materials that are currently available. ^{222}Rn activity in gaseous nitrogen can be reduced to the level of 0.3 μBq/m^3 [7]. The copper vessel is surrounded by a water buffer, as additional shielding against external γ radiation and neutrons. The water volume is equipped with photomultipliers to provide a Cherenkov veto against muon-induced background. To complete the 4π coverage of the muon-veto, plastic scintillators are foreseen on top of the set-up. High-Z materials (like copper and lead) are minimized in the vicinity of the detectors in order to limit the muon-induced production of neutrons. The lock, the clean room, the electronics and the data-acquisition are located on top of the water tank, inside the so-called penthouse.

The GERDA experiment will proceed in a phased approach with the sensitive mass of the experiment progressively increasing.
In the first phase (Phase I) the already existing HP-Ge detectors (enriched to 86% in ^{76}Ge) from the Heidelberg-Moscow and IGEX experiments will be operated. Their total mass is about 19 kg. The background level for Phase I is expected to be limited to 10^{-2} counts/keV/kg/y by the cosmogenic ^{60}Co activation of the existing detectors.

Since $0\nu\beta\beta$ events are inherently single-site (i.e. localized in a small volume), while most γ events produce multiple-site interactions, background can be rejected using anticoicidences between different detectors and pulse shape analysis. Following Ref. [3] about 6 $0\nu\beta\beta$ events are expected (on a background of 0.5) in an exposure of 15 kg$\cdot$ y, corresponding to one year of data taking in the Phase I. The equivalent sensitivity on the half-life is about $3 \cdot 10^{25}$ y (90% CL) which should allow a statistically unambiguous statement concerning the central value given in Ref. [3].
In the second phase (Phase II) new enriched Ge detectors with a total mass of at least 20 kg will be installed. 37.5 kg of enriched germanium (86% in ^{76}Ge) have been produced by the ECP Company in Zelenogorosk (Russian Federation). The new detectors will be truely coaxial and segmented. The background suppression efficiency will be increased by using anticoincidence between different segments. The foreseen segmentation scheme is 18-fold, with 6 segments in ϕ and 3 in z (i.e. along the core axis). Particular care will be devoted to minimize the cosmogenic activation of the enriched material. The storage will be underground and the total time on the surface for crystal growing, diode production and transport to the Gran Sasso Laboratory will be kept as short as possible (about ten days). The background level foreseen for Phase II is below 10^{-3} counts/keV/kg/y. The half-life sensitivity aimed at is a minimum of $2 \cdot 10^{26}$ y (90% CL).

PRESENT STATUS OF GERDA

The project has been approved and funded. Space has been allocated in the Hall A of the Gran Sasso Laboratory in front of the LVD experiment. The infrastructure including water tank and cryostat are under final design. Work on the existing diodes (refurbishment, characterization) has started. 37.5 kg of enriched material have been procured to produce new detectors. The definition of read-out and DAQ electronics is ongoing.
Monte Carlo background studies are being performed within a GEANT4-based framework called MAGE. It is jointly developed with the Majorana $\beta\beta$-decay experiment.
The installation will start in 2006.

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